what they can to guard themselves against it. They begin to purify their houses by lighting fires in every room, and in certain towns they abstain from pork. Mr. Rocher gives details as to the symptoms and course of the disease. With regard to the track of the epidemic Mr. Rocher observed a peculiar fact both in the north and south of the province. Instead of visiting every village in its direct line of progress it would pass some completely by, visiting places near them and on both sides, to return to those forgotten spots several months afterwards, when the epidemic would appear to have passed far away. Another fact not less curious is that after having appeared in almost every one of the villages scattered about the plains, it frequently ascends the mountains, where, among the aborigines who inhabit the high lands, it claims many victims. We may add that Mr. Rocher's notes are accompanied by a map, compiled from private and official memoranda, which shows the course followed by the plague in 1871, 72, and 73 ; it was not possible, however, to include in it the towns in the west of the province, which was at that time the theatre of the war between the Imperialists and the Mahometan rebels, as the information obtainable was quite untrustworthy, but it is certain that the epidemic was constantly present among the Imperialist troops.

THE additions to the Zoological Society's Gardens during the past week include a Green Monkey (*Cercopithecus callitrichus*) from West Africa, presented by Miss G. E. Marryat ; a Bonnet Monkey (*Macacus radiatus*) from India, presented by Mr. F. Hinde ; two Horsfield's Tortoises (*Testudo horsfieldi*) from Turkestan, presented by Dr. Alex. Strauch, C.M.Z.S. ; a Wanderoo Monkey (*Macacus silenus*) from Malabar, two Egyptian Jerboas (*Dipus ægyptius*) from Egypt, a Sun Bittern (*Eurypyga helias*) from South America, deposited ; a Woodcock (*Scolopax rusticola*), European, purchased.

CHARLES ADOLPHE WURTZ

IN connection with the Faraday Lecture which follows, it may interest our readers to have a few particulars as to the life and work of the lecturer, Prof. Wurtz.

Charles Adolphe Wurtz was born at Strassburg on November 16, 1817. He commenced his chemical career as assistant to Dumas, and first acquired an independent position as professor at the Agricultural Institute at Versailles. For the last thirty years he has been Professor of Chemistry at the École de Médecine, Paris ; in addition to which he now holds the post of Professor of Chemistry at the Sorbonne.

Prof. Wurtz is a member of the Institute (Académie des Sciences), and a foreign Fellow of the Royal Society.

Some idea of the energy which he has displayed as an investigator is conveyed by the fact that a list of no less than seventy-three titles of papers is appended to his name in the Royal Society Catalogue, which only includes papers published previous to 1864. Much of his work is of the first importance in connection with chemical theory, and he undoubtedly takes rank as one of the chief pioneers of modern organic chemistry.

His first investigation, published in 1842, was on the constitution of the hypophosphites ; this was followed by researches on phosphorous acid, sulpho-phosphoric acid, &c., which greatly added to our knowledge of the phosphorus compounds. It was in the course of his experiments on the hypophosphites that Wurtz discovered hydride of copper, Cu_2H_2, one of the most remarkable hydrides with which we are acquainted, and especially interesting as, with the exception of potassium, sodium, and perhaps palladium, none of the metals appear to be capable of combining with hydrogen. Hydride of copper is formed as a yellowish precipitate on adding a concentrated solution of copper sulphate to a solution of hypophosphorous acid, and warming the mixture to about

70° C. ; in the dry state it slowly decomposes into its constituents at about 55° C. ; concentrated hydrochloric acid at once dissolves it with evolution of hydrogen, although copper is not in the least affected by this acid, and what is most remarkable, both the hydrogen of the acid and of the hydride of copper are given off as shown by the equation—

$$Cu_2H_2 + 2HCl = Cu_2Cl_2 + 2H_2.$$
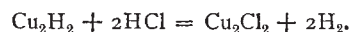
The study of certain cyanogen compounds—the cyanic and cyanuric ethers—next engaged his attention, and his researches on these bodies culminated in the remarkable discovery, in 1849, of the so-called compound ammonias formed by the displacement of one of the atoms of hydrogen in ammonia, NH_3, by organic radicles, such as methyl, CH_3, ethyl, C_2H_5, &c.

A third investigation to which we may here refer is that on the alcohol radicles published in 1855. Frankland had shown that the hydrocarbon radicles which it was assumed were contained in the alcohols could actually be isolated ; that, from ordinary or ethyl acohol, for example, which may be regarded as a compound of the radicle ethyl, C_2H_5, with the radicle OH, we may obtain ethyl by acting with zinc on the iodide which it yields on treatment with hydriodic acid, thus withdrawing the iodine from it, just as the iodine is withdrawn from the hydrogen in hydriodic acid by the action of metals ; and Kolbe had obtained similar results with acids, such as acetic acid, by submitting solutions of their salts to the action of a powerful electric current. These chemists, however, supposed that the radicles thus withdrawn from combination with other radicles remained in the free state, but Laurent and Gerhardt, and Hofmann argued on theoretical grounds that the bodies thus produced were not the radicles themselves but compounds of the radicles with themselves—that ethyl, for example, was not C_2H_5, but C_4H_{10} or $C_2H_5 + C_2H_5$. Conclusive evidence of the correctness of this latter view was afforded by Wurtz's discovery that if a mixture of the iodides of two different radicles were treated with metallic sodium, a hydrocarbon formed by the union of the two different radicles was obtained. This discovery has afforded one of the chief arguments in favour of the view now almost universally entertained by chemists, that free hydrogen is a compound of hydrogen with hydrogen.

The mere recapitulation of the titles of his remaining investigations would alone occupy a large amount of space. We can only refer to those on the glycols and on ethylene oxide ; on the action of nascent hydrogen on aldehyde ; on the action of chlorine on aldehyde, both in the anhydrous state and in presence of water ; on the action of hydrochloric acid on aldehyde ; on the synthesis of neurine ; and on abnormal vapour densities, as being, among others, of especial interest.

ON THE CONSTITUTION OF MATTER IN THE GASEOUS STATE [1]

LADIES AND GENTLEMEN,—

I ESTEEM it a great honour to address you within these walls, about which there still hovers the ever fresh memory of him whose name we celebrate to-day, while we deplore his loss. I am fully sensible both of the great value of this honour and of the danger that attends it, and I have need to shelter myself under the authority of the great name of FARADAY. I have, therefore, chosen a subject connected with his earliest discoveries. The constitution of matter is a question of the highest importance with regard both to physics and to chemistry. The word "gas" was introduced into science by Van Helmont, who, at the beginning of the seventeenth century, first pointed out, with some degree of precision, the differences existing be-

tween certain aëriform fluids. He it was who first spoke of *Gas silvestre*, formed by the combustion of charcoal, and given off during the fermentation of beer. To him, also, we owe the distinction—which kept its ground for two centuries—between gases and vapours. He regarded gases as aëriform fluids, incapable of reduction to the liquid state by cooling, whereas vapours require the aid of heat to maintain them in the gaseous state. An important difference of constitution seemed, therefore, to exist between these two kinds of aëriform fluid. This difference, however, is not fundamental, and the distinction between gases and vapours has disappeared, in a theoretical point of view, being, in fact, reduced to a simple question of temperature and pressure.

On March 13, 1823, Faraday, then a young man engaged as chemical assistant at the Royal Institution, read before the Royal Society a note entitled "On Fluid Chlorine." He had succeeded in condensing this gas to a liquid by a process which has become classical. This process consists in heating in a closed vessel placed in a water-bath crystals of chlorine hydrate. This compound, very rich in chlorine, is resolved at a gentle heat into chlorine and liquid water, the quantity of which is not sufficient to dissolve the whole of the chlorine. The latter is therefore disengaged in great part in the state of gas, which accumulates in the small space remaining to it, and is liquefied by the pressure which it exerts upon itself.

On the same day Sir Humphry Davy read a note "On the Liquefaction of Hydrochloric Acid Gas," which he effected by decomposing sal-ammoniac with sulphuric acid in a closed vessel. These researches were completed by Faraday, who, on April 10 of the same year, described the liquefaction of a large number of gases, directing his efforts, by Davy's advice, chiefly to those which are dense, or very soluble in water, such as sulphurous acid, ammonia, sulphuretted hydrogen, carbonic acid, and protoxide of nitrogen.

To enumerate the special processes adopted in each particular case would occupy too much time. We shall therefore merely observe that the chief, if not the only, means of condensation adopted in these experiments was compression, that is to say, the reduction of the gas to a small volume, and that this compression was exerted by the gas upon itself, as it accumulated in the very strong sealed glass tubes in which it was disengaged. Sir Humphry Davy, in the note above cited, had remarked that pressure appeared to be a more efficacious method of condensation than cooling, inasmuch as a double pressure reduces the volume of the gas to one-half, whereas a depression of temperature of 1° F. reduces the volume by only $\frac{1}{480}$, the lowering of temperature, moreover, soon attaining an impassable limit. It must, however, be especially observed that, even in his first experiments, Faraday made use of differences of temperature, if not to liquefy the gases, at all events to distil and isolate the liquids. Thus it was in the case of chlorine, for example, and in that of ammonia, which he liquefied by heating ammoniacal silver chloride in a bent tube sealed at both ends, the ammonia then distilling over and collecting in the empty branch of the tube, which was cooled to a low temperature.

Similar phenomena will be exhibited in the experiment which I am about to show you, consisting in the liquefaction of cyanogen gas by heating cyanide of mercury in a small glass tube terminated by a long capillary tube bent in the form of the letter U. The figure of this curved portion will be projected on a screen by the electric light, and in a few seconds you will see the liquid cyanogen collect in the bend.

Before leaving this part of my subject, I would recall to your attention two of Faraday's discoveries resulting from the application of the principles just explained. Having compressed coal-gas to twenty-five atmospheres, Faraday in 1825 discovered two important bodies, namely, butylene, a compound of great importance in a theoretical point of view—and benzene—so named by Mitscherlich several years afterwards—which in our own time has become the object of numerous and important applications, and the pivot of an entire department of chemistry.

Another instance is afforded by sulphurous acid gas (SO_2), which was liquefied by Bussy in 1824, at the ordinary atmospheric pressure, by the effect of a cold of 12° to 15° below zero.

Whether we condense gases by pressure or reduce them to the liquid state by diminution of temperature, the result of either method is to bring their particles closer together. It would seem then, in accordance with Davy's view, that pressure ought to be more efficacious, as a means of condensation, than cooling.

Nevertheless it is not so. The mere approximation of the particles of certain gases does not suffice to effect their liquefaction, and moreover, the distances between the particles cannot be diminished indefinitely by pressure alone. M. Natterer, of Vienna, has compressed oxygen, hydrogen, and nitrogen to 3,000 atmospheres without effecting their liquefaction. These gases, hitherto called permanent, cannot be liquefied by pressure alone, and their liquefaction, which has quite recently been effected, is the joint effect of strong pressure and a great degree of cold. This is the important point, and I request your permission to offer in this place a few explanations which will serve to place it in its true light.

The impossibility of liquefying certain gases by pressure alone is in accordance with the ideas which are current at the present day respecting the nature of aëriform fluids, and likewise with a discovery made in England within the last few years, on the continuity of the gaseous and liquid states. I will explain myself briefly on these two points.

Daniel Bernouilli first enunciated the idea that gases are formed of material particles, free in space, and animated by very rapid rectilinear movements, and that the tension of elastic fluids results from the shock of their particles against the sides of the containing vessels. Such is the origin of the kinetic theory of gases, which has been revived since 1824 by Herapath, Joule, and Krönig, and developed chiefly by Clausius and Clerk Maxwell.

The law of Boyle and of Mariotte follows as a natural consequence of this idea. Suppose a gas occupying a certain volume, and composed of a definite number of material particles —or molecules so-called—to be contained in a closed vessel, such as the cylinder of an air-pump; the pressure on the piston will be determined by the number of shocks of the molecules diffused through the neighbouring stratum of gas. If, then, the volume of the gas be reduced, the number of particles in this layer will be increased, as well as the sum of the shocks, and the pressure will be increased in proportion thereto.

The velocities with which these molecules move are enormous. Clausius supposes that the molecules of air move with a mean velocity of 485 metres per second, and those of hydrogen with a mean velocity of 1844 metres per second. I say mean velocity, for all the particles of a gas do not move at the same rate. But can the particles freely traverse these wide spaces? By no means; their number is so immense, that at every instant they enter into collision with one another, and rebound in such a manner that their motion is altered both in velocity and in direction. It follows, therefore, that the molecules of a gaseous mass are continually moving in all directions with variable velocities, their motion in the intervals between the collisions being sensibly rectilinear. The distribution of the velocities has been made the subject of important researches by Clerk Maxwell.

These movements of gaseous molecules determine a very important physical condition, namely, temperature. In fact, the energy of the rectilinear movements, that is to say, the mass of the gaseous molecules multiplied by the square of their velocity, gives the measure of the temperature, which consequently increases proportionally to the energy of the rectilinear movement, or, for the same gas—since the masses remain constant—it increases as the square of the velocity. If the velocity were reduced to nothing, the calorific motion would be annihilated, that is to say, the gas would be entirely deprived of heat. This state corresponds with the absolute zero.

The gaseous molecules moving in all directions and coming into collision with one another in space, are very nearly emancipated from cohesion. Nevertheless this attractive force makes itself felt for the infinitely short time during which the molecules actually touch one another, or are on the point of doing so. This influence of cohesion is one of the causes of deviation from the law of Boyle or of Mariotte.

In liquids the influence of cohesion is manifest, preventing the molecules from separating, though it allows them to glide one over the other. This molecular cohesion, or attraction, is in continual strife with the force of expansion, or kinetic energy, which, if unopposed, would launch the molecules into space.

To understand the antagonism between these two forces, consider for a moment a saturated vapour in contact with the liquid from which it has been formed. When it is reduced to a smaller volume, a certain number of its molecules are brought within the sphere of action of cohesion; they are consequently aggregated together and precipitated in the liquid state, while the rest, being

now diffused through a wider space, continue to move with the same velocity and to exert the same pressure as before. In this case the force of cohesion of the liquid particles exactly balances the expansive force or kinetic energy, and serves to a certain extent as a measure of its amount.

Now let the vapour be heated, after it has been withdrawn from the action of the liquid; its expansive force will then increase; it will dilate, and may then be compressed, until, by the approximation of its particles, it is again brought within the sphere of action of the cohesive force, that is to say, to the point of saturation corresponding with the temperature to which it has been raised. With the increase of temperature, the expansive force or kinetic energy of the vapour likewise increases, whereas the cohesion of the liquid becomes less: hence the necessity of further diminishing the distances between the particles by increase of pressure. But this double effect of increased kinetic energy of the gaseous molecules, and diminished cohesion of the liquid molecules, going on progressively as the temperature rises, a point will at length be attained at which the energy of the molecular movement will finally gain the victory over the force of cohesion, *whatever be the pressure to which the vapour is subjected*. The minimum temperature at which this effect is produced, and at which, therefore, a vapour can no longer co-exist with its liquid under any pressure whatever, has been called by my friend, Dr. Andrews, the c r i t i c a l p o i n t, and by M. Mendelejeff, the a b s o l u t e b o i l i n g p o i n t. Above this temperature, whatever may be the pressure, the gas, whether dilated or compressed, will maintain the same physical state, characterised by freedom of molecular or calorific movement.

I can show you by an experiment this peculiar phenomenon of the sudden passage of a liquid mass to the state of gas, by heating liquid carbonic acid in a closed vessel, just as Cagniard de Latour formerly heated ether. Here is a tube, half filled with liquid carbonic acid, which we are about to immerse in water at 35°; you observe that the liquid first rises quickly in the tube, its coefficient of expansion being greater than that of gases; at the same time the meniscus flattens more and more, indicating a diminution of cohesion in the liquid (Andrews), and finally disappears altogether; in fact the liquid itself has disappeared, having been entirely and suddenly transformed into gas. What now must we do to cause it to reappear? We must lower the temperature, so as to diminish the kinetic energy of the gas, and increase the cohesion of the liquid. A moment will then arrive when the cohesive force will again be able to resume the contest, and the liquid will be reconstituted.

We are now in a position to understand why certain gases, hitherto called *permanent*, cannot be liquefied except by the combined action of very strong pressure and a very great degree of cold. The critical points of these gases are situated at very low temperatures. They have quite recently been liquefied, this great discovery having been made by MM. Cailletet and Raoul Pictet.

The principle of Cailletet's apparatus is the following:—The gas to be liquefied is introduced into a cylindrical glass vessel and transferred by means of mercury to a very strong glass tube sealed into the reservoir. This latter is firmly fixed in a cylindrical cavity hollowed out of a block of iron, and serving as a kind of closed mercurial trough. The cylindrical cavity communicates with a hydraulic press which injects water on to the surface of the mercury, driving it into the gas reservoir, which is ultimately quite filled with that liquid, the gas being thereby driven into the tube, where it is liquefied.

In this manner we shall be able by a few strokes of the piston of the hydraulic press to liquefy carbonic acid. Other gases less easily condensable may be liquefied in a similar manner, if the tube be cooled to − 20° or − 30°. But these temperatures do not suffice for the liquefaction of the so-called permanent gases. To cool these gases to lower temperatures, M. Cailletet avails himself of sudden expansion (*détente*). The gas, compressed to several hundreds of atmospheres, when allowed to expand suddenly and drive the air before it, consumes a certain quantity of heat, and is thereby reduced to a kind of mist, which will appear on the screen, and pass away like a cloud, if we suddenly expand the strongly compressed carbonic acid gas, which we have here, in default of oxygen or hydrogen.

M. Raoul Pictet has succeeded in condensing oxygen and hydrogen in the form of liquids, properly so called, and even in obtaining the latter of these gases in the solid state. To produce this effect, he employs condensing apparatus of incomparable power, combining the action of a cold of 120° to 140° below zero with that of enormous pressures amounting to 550 and even 650 atmospheres. The pressure is produced by the accumulation of the gases in a closed space consisting of a long copper tube of very thick metal. The oxygen was produced by heating potassium chlorate in a howitzer shell, having a copper tube soldered into its orifice. The hydrogen was prepared in a similar apparatus, by decomposition of a dry mixture of potassium formate and potassium hydrate.

To produce very low temperatures of 120° or even 140° below zero, M. Pictet resorts to a very ingenious artifice. Over the reservoir-tube which surrounds the copper tube, and in which these low temperatures are intended to be produced, he superposes another system of concentric tubes, intended to produce a first fall of temperature amounting to − 65°, by the volatilisation of liquid sulphurous acid. By means of this first depression of temperature it has been found possible to liquefy carbonic acid gas in the inner tube of the system just mentioned, by a pressure of only a few atmospheres. The carbonic acid thus liquefied being introduced into the lower reservoir-tube of the apparatus, produces by its volatilisation, a second fall of temperature round the copper tube containing the compressed oxygen which is to be liquefied. M. Pictet has in fact established a double circulation, one of sulphurous acid, the other of carbonic acid. I will describe the former. Sulphurous acid gas is liquefied by a pressure of three atmospheres and collects in a strong vessel, from which it passes through a tube into the upper reservoir. The pressure is exerted by means of a force-pump. A suction-pump connected with the force-pump, and acting in concert with it withdraws the liquid sulphurous acid from the reservoir-tube, and transfers it to the force-pump, which brings it back to the vessel, and thence to the upper reservoir-tube.

The circulation of the carbonic acid is established in the same manner, by means of two pumps, one of which condenses the gas by forcing it into tubes cooled to − 61°, while the other, which is a suction-pump, sends it back to the force-pump. The volatilisation of the carbonic acid produces round the copper tube the low temperatures above-mentioned. The copper tube is in fact surrounded by solid carbonic acid.

In this manner M. Pictet has liquefied o x y g e n, and has approximately calculated its density. He has also liquefied and even solidified h y d r o g e n, which he has seen to issue from the tube in the form of a steel-blue liquid jet, which partly solidified. The solid hydrogen, in falling on the floor, produced the shrill noise of a metallic hail, thus confirming the bold and ingenious idea of Faraday, who first suggested that hydrogen is a metal.

The experiments of MM. Raoul Pictet and Cailletet have then removed from science the distinction between permanent and condensable gases. Permanent gases exist no longer. All aeriform fluids may be liquefied with a facility greater in proportion as their critical points are situated at higher temperatures. From a physical point of view, therefore, gases and vapours have the same constitution, being formed of molecules which move freely in space. In what, then, do they differ? They differ by the nature and constitution of these molecules; and here we enter on the domain of CHEMISTRY.

It is supposed, in chemistry, that the molecules of each species of gas or vapour are formed of a definite number of atoms. The simplest molecules, like those of mercury-vapour, are formed of single atoms. Others include several atoms of the same or of different kinds; and these latter molecules may be very complex, that is to say, formed of a large number of atoms held together by affinity, and vibrating in concert in a system to which they are attached, viz., the molecule. In this system, which has a definite form, extent, and centre of gravity, the molecules execute their own proper movements, and are at the same time carried forward with the entire system in the molecular paths.

I cannot here dilate on the nature and chemical properties of the several gases and vapours. I wish merely to throw light on a single point, which is of great importance, inasmuch as it constitutes one of the foundations of chemical science.

The proposition which I am about to enunciate is generally adopted by chemists, resting as it does on an imposing array of facts: *Equal volumes of gases or vapours, under the same conditions of pressure and temperature, contain equal numbers of molecules.*

The Italian chemist, Amadeo Avogadro, in discussing the discoveries of Gay-Lussac respecting the simple relations which exist between the volumes in which gases combine, was the first to recognise that there likewise exists a simple relation between the volumes of gases and the number of molecules which they contain. The simplest hypothesis, said he, that can be made regarding this matter consists in supposing that all gases contain in equal volumes equal numbers of "integrant molecules." By this term he denoted what we now call simply *molecules*, and he distinguished these integrant molecules from the "elementary molecules" which we call *atoms*. According to him the integrant molecules of gases are all equally distant one from the other, and these distances are so great in proportion to the dimensions of the molecules, that the mutual attraction between the latter is reduced to nothing.

These integrant molecules are composed of a greater or smaller number of elementary molecules, not only in compound, but likewise in simple bodies; the integrant molecules of chlorine, for example, are composed of four elementary molecules, and the same is the case with the integrant molecules of hydrogen. What happens, then, when chlorine and hydrogen combine together? The integrant molecules of these two bodies are then resolved into elementary molecules, which combine, two by two, to form hydrochloric acid.

Ideas analogous to those of the Italian chemist were enunciated in 1814 by Ampère, and thus there has been introduced into chemical science the notion that there exist two kinds of small particles, namely, m o l e c u l e s and a t o m s, the former being diffused in equal numbers through equal volumes of gases.

But this notion, so clearly enunciated more than sixty years ago, was afterwards destined to be obscured. Berzelius, taking up Ampère's proposition, altered it by substituting atoms for molecules, and saying that "equal volumes of gases contain equal numbers of atoms." This proposition, which has given rise to long discussions, must now be rejected, for it is inexact. It is to Gerhardt, and more recently to Cannizzaro, that is due the honour of having restored the thesis of Avogadro and Ampère, and pointed out its importance in connection with chemical theory. This I must explain in conclusion.

In the first place Gerhardt simplified the rule of Avogadro. The latter supposed that a molecule of chlorine or of hydrogen contains four atoms, whereas Gerhardt regards it as consisting of two. Avogadro's proposition thus modified, assumes a very simple form, and may be enunciated in the following terms. Suppose that a volume, or the unit of volume, of hydrogen contains one atom; then the molecules of all gases and vapours will occupy two volumes. Thus, a molecule of hydrogen formed of two atoms will occupy two volumes, and a molecule of chlorine formed of two atoms will likewise occupy two volumes. What now will happen when chlorine combines with hydrogen? The molecules will be cut in two, and each of the two chlorine-atoms uniting itself to an atom of hydrogen, two molecules of hydrochloric acid will be formed, each occupying two volumes. Thus if an atom of hydrogen occupies one volume, a molecule of hydrochloric acid will occupy two volumes. The same is the case with the molecules of all other gases and vapours.

A molecule of water formed of 2 at. H and 1 at. O occupies 2 volumes.
　　,,　　ammonia　　,,　　3 at. H and 1 at. N　　,,　　　,,
　　,,　　marsh gas　,,　：4 at. H and 1 at. C　　,,　　　,,

This list might be prolonged by taking as examples a large number of gaseous or volatile bodies belonging both to mineral and to organic chemistry, and including chlorinated, brominated, and oxygenated compounds of the metalloids, and of a large number of metals. The countless volatile compounds of organic chemistry, hydrocarbons, alcohols, chlorides, bromides, organo-metallic compounds, compound ammonias, aldehydes, ketones—all this legion of various compounds—conform to the law of Avogadro and Ampère, their molecules occupying two volumes if an atom of hydrogen occupies one volume. Hence it follows that the relative weights of two volumes represent the relative weights of the molecules, or the m o l e c u l a r w e i g h t s. To find these latter, therefore, it is sufficient to double the numbers which express the weights of a single volume, or of the unit of volume, that is to say the densities. The densities of gases may be referred to that of hydrogen as unity, and the atomic weights to that of hydrogen. The unit being then the same, it follows that the numbers which express the double densities referred to hydrogen will also represent the molecular weights.

Chemists represent the constitution of molecules by formulæ, each of which shows the number of atoms condensed within the molecule. Now the molecular weights being known, it is very easy to deduce the formulæ from them, as these formulæ must represent the number of atoms comprised in two volumes. Such is the relation which exists between the Law of Volumes and Chemical Notation. The rule of Avogadro and Ampère has, in fact, become one of the bases of this notation. There are, however, certain exceptions to its generality, but they are probably more apparent than real. Sal-ammoniac, ammonium sulphhydrate, phosphorus pentachloride, iodine trichloride, sulphuric acid, calomel, amylene hydrobromide, and chloral hydrate, have vapour-densities such that their molecules appear to occupy four volumes. Such, however, is not the case; and it may be shown that the bodies in question do not volatilise without decomposition, but that, when they are heated, their molecules split up into two, each of which occupies two volumes. Being unable to analyse all the cases above-mentioned, I will confine myself to the last, viz., c h l o r a l h y d r a t e, which has given rise to a long discussion.

The question to be decided is, whether this compound is or is not decomposed by conversion into vapour? If it really suffers decomposition, it should be resolved into anhydrous chloral and water. That this decomposition really takes place may be shown by a method based on the theory of dissociation developed by M. H. Sainte-Claire Deville.

Here is the case in a few words. We have here in a tube a certain volume of the vapour of chloral hydrate under a certain pressure; it is required to show that this vapour contains vapour of water. For this purpose we are about to introduce into it a body capable of emitting vapour of water, crystallised potassium oxalate, for example. If the atmosphere is dry, this salt will give off vapour of water just as it would in dry air or in vapour of chloroform at the same temperature, and it will continue to emit this vapour until the atmosphere shall have taken up a degree of humidity corresponding with that which is designated by M. H. Sainte-Claire Deville the *dissociation tension* of the hydrated salt in question. If, on the other hand, the chloral atmosphere is moist, and exhibits exactly the degree of humidity just defined, the crystallised oxalate will not emit any water. In this first tube, then, we have the vapour of chloral hydrate; the second contains vapour of chloroform. This latter is dry, and I am about to prove to you that the former is moist. In fact, the crystallised potassium oxalate which we are introducing into the chloroform tube will rapidly depress the level of the mercury by emitting vapour of water, whereas in the atmosphere of chloral hydrate it will not emit vapour of water, and consequently will not depress the level of the mercury. This shows that chloral hydrate undergoes decomposition when converted into vapour, and this supposed exception to the rule of Avogadro and Ampère vanishes, like all the rest, when submitted to the test of experiment. This rule appears, then, like a grand law of nature, as simple in its enunciation as it is important in its consequences.

Such are the considerations which I wished to lay before you on the physical and chemical constitution of gases. Does not this exposition seem to show that, of all the states which matter can assume, the gaseous state is the most accessible to our researches, and the best known—not, indeed, that we can affirm the certainty of the theoretical considerations which I have brought before you, for they are but probable. In the physical sciences nothing is certain but well-observed facts and their immediate consequences; and, whenever we attempt to make these facts the basis of any general theory, hypothetical data are apt to mix themselves up with our deductions. In the present case the hypothesis consists in assuming that gases, and matter in general, are formed of molecules, and these latter of atoms. §No one has ever seen these molecules and atoms, and it is certain that nobody ever will see them. Does it follow then that we ought to reject or disdain this hypothesis? By no means. Our theories may be verified in their consequences, and may thereby acquire a certain degree of probability. The theory under consideration has been subjected to this ordeal, and nothing has hitherto been found to contradict it. It is probable, indeed, that gases are composed of small particles moving freely in space, with immense velocities, and capable of communicating their motion by collision or by friction. It is probable that these molecules are diffused in space in numbers so enormous that the most rarefied spaces still contain legions of them; and it is this circumstance which explains the possibility of the movements of the radiometer.

Be this as it may, the idea of Daniel Bernoulli has been deve-loped into a beautiful theory—the kinetic theory of gases—a theory which has shed a sudden clearness, an unexpected light, on matters which seemed to be veiled in the deepest obscurity. The molecules, as already stated, are invisible. Never-theless, attempts have been made to pene.rate this invisible world by the force of scientific reasoning, and by an effort which does honour to the human mind, even if it be destined to remain barren. The illustrious authors of the kinetic theory of gases have sought to determine, not only the velocities of the gaseous molecules, and the prodigious number of their collisions during a unit of time, but likewise their distances, their abso-lute dimensions, and their number in a given volume. And here we arrive at results which bewilder the imagination, but which, in this lecture, I must not attempt to unfold.

Permit me only to add that these great labours mark a resting place in our course, and are, perhaps, an approach towards the solution of the eternal problem of the constitution of matter—a problem which dates from the earliest ages of civilisation, and though discussed by all the great thinkers of ancient, as well as of modern, times, still remains unsolved. May we not hope that in our own time this problem has been more clearly stated and more earnestly attacked, and that the labours of the nineteenth century have advanced the human mind in these arduous paths, more than those of a Lucretius, or even of a Descartes and a Newton. From this point of view, the discoveries of modern chemistry, so well expressed and sum-marised by the immortal conception of Dalton, will mark an epoch in the progress of the human mind ; and to one of the most important among these discoveries—that of the liquefaction of the gases—grateful posterity will for ever join the glorious name of FARADAY.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

BIOLOGISTS will be pleased with the frank recognition of Dr. Foster's services contained in the statute proposed by the Council of the Senate at Cambridge for the new Professorship of Physiology to be founded by Trinity College. It is to be permanently re-corded that Dr. Foster's lectures have always been open to the entire University, and that he "has successfully promoted" the study of physiology. Thus the continued self-denying effort and enthusiasm which have in eight years developed a school of over seventy students, and which have called forth the original talents of a score of ardent young investigators, will find still fuller scope. We understand that Dr. Foster resolutely de-clined to sanction any arrangement by Trinity College to secure for him the first tenure of the professorship, preferring to leave the University perfectly unfettered in its choice. But the Coun-cil of the Senate, which is a thoroughly representative body, chooses to signify the inseparable connection of the work with Dr. Foster's name by the very wording of the statute. The professor is to be elected by a board consisting of the Vice-Chancellor, of four members nominated by the Council, and four nominated by the Board of Natural Science Studies. One of each four must be neither resident in the University nor officially connected with it.

THE Cambridge mechanical workshops, organised by Prof. Stuart, bid fair to become of importance to research in the country generally, as well as in Cambridge. Prof. Stuart, on his own responsibility, has completely fitted up the workshops with all machinery necessary for the construction of philosophical apparatus. He has engaged a number of the most competent workmen as teachers, and to construct apparatus required by professors and investigators who are often deterred from re-searches because of lack of appliances or time to make what they want. Classes are formed for the regular instruction of university men in the use of tools and the construction of machines, and these are attended at present by a dozen students, several of whom intend to become engineers.

MR. A. C. HADDON, of Christ's College, has been nominated by the Board of Natural Sciences Studies, Cambridge, to study at the Zoological Station at Naples during the ensuing season.

DR. GREENFIELD, of St. Thomas's Hospital, has been appointed by the Senate of the University of London to succeed Dr. Burdon Sanderson as Professor of Comparative Pathology at the Brown Institution.

THE subscriptions already received or promised for the ex-tension of the buildings of University College, London, amount to upwards of 14,000*l.*

BY the will of the late Mr. Charles Randolph, engineer, 60,000*l.* has been left to the building fund of Glasgow University.

THE third annual report of the Johns Hopkins University, Baltimore, issued by President Gilman, is of the highest interest, and shows that the attempt to establish a purely philosophical university has been eminently successful. Our readers are no doubt familiar with the principles on which this institution has been based. It was not sought to add one more to the many colleges already existing in the United States, but to found a genuine university in which those who had the inclination and the capabilities would have every facility for carrying their elementary or collegiate studies into the region of research in the various departments of human knowledge. The method of work has been carefully planned ; the best men obtainable have been got to superintend the work of the students, who are admitted only on showing that they are really able and willing to pursue the courses which have been arranged. It is a many-sided and active centre of the highest learning, and cannot but have an invigorating result on science in all its depart-ments in the United States. We would recommend those of our readers interested in the higher education to procure a copy of this report, which deserves a more detailed notice than we have space for.

THE Budget for Public Instruction will be deposited this week in the Bureau of the French Chamber of Deputies. A large increase is asked for in favour of public instruction. The credit granted will exceed two millions sterling. In 1823 it was only two thousand pounds, consequently in a little more than half a century it has been multiplied a thousand-fold. M. Bardoux will propose the creation in each department of a high school for popular education according to the models which have proved so successful in Paris. The benefit of the organisation realised in the capital will be extended to the whole of France if the scheme of the active minister is adopted, as will most probably be the case.

AT Stockholm the "Free" University was opened on October 14 last. The funds collected for its foundation now reach the sum of 820,000 Swedish crowns. It is intended to establish a similar university at Gothenburg.

SCIENTIFIC SERIALS

The American Journal of Science and Arts, October.—Besides two valuable papers by Professors Mayer and Draper, reproduced in our columns, we have here an account of the curious artificial mounds of North-Eastern Iowa, by Mr. McGee. They consist of tumuli, smaller conical mounds, embankments, and animal mounds, and from numerous measurements the builders seem to have used a unit which either was, or grew out of, the pace or yard. A slow southerly migration of the mound-builders is supposed to explain the evident increase in geometrical know-ledge attested by various works found in passing across the United States from north to south.—Prof. Young furnishes details of observations of the Princeton Eclipse Expedition.—The flour-mill explosion at Minneapolis in May was probably due to the running dry of a set of stones which ground middlings, one of six sets discharging into a spout which communicated with a dust-house. Mr. Peckham studies the case, pointing out that there is greater danger with middlings, because it is dryer, and is ground at a higher temperature, and finer. The dry stones may heat the last part of the grist remaining, sufficiently to make it like tinder, so that it readily ignites on receiving a spark from the stones. The practical problem is how to prevent or detect dry stones, especially those for middlings.—Mr. Becker indicates the *rationale* of correction for vacuum in chemical analysis.—Prof. Smith writes on the composition of the new meteoric mineral, Daubreelite, and its frequent, if not universal, occurrence in meteoric irons.—Prof. Watson gives a more careful determination (than previously) of the intra-Mercurial planets.

Annalen der Physik und Chemie.—No. 9, 1878.—The excitation of electricity on contact of solid and gaseous bodies, forms the subject of an opening paper by Herr Beetz, who thinks the case is either one of differences of tension produced by different conducting liquids, or of change of metals by gases which have ceased to be in the gaseous state, either through occlusion in the metals, or con-densation on their surface.—From experiments on production of